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Design Patterns for an Interactive Storytelling Robot to Support Children's Engagement and Agency

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ABSTRACT

In this paper we specify and validate three interaction design patterns for an interactive storytelling experience with an autonomous social robot. The patterns enable the child to make decisions about the story by talking with the robot, reenact parts of the story together with the robot, and recording self-made sound effects. The design patterns successfully support children's engagement and agency.

A user study (N = 27, 8-10 y.o.) showed that children paid more attention to the robot, enjoyed the storytelling experience more, and could recall more about the story, when the design patterns were employed by the robot during storytelling. All three aspects are important features of engagement. Children felt more autonomous during storytelling with the design patterns and highly appreciated that the design patterns allowed them to express themselves more freely. Both aspects are important features of children's agency.

Important lessons we have learned are that reducing points of confusion and giving the children more time to make themselves heard by the robot will improve the patterns efficiency to support engagement and agency. Allowing children to pick and choose from a diverse set of stories and interaction settings would make the storytelling experience more inclusive for a broader range of children.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in interaction design**; • **Computing methodologies →** *Cognitive robotics*; • **Applied computing →** *Consumer health.*

KEYWORDS

Child-Robot Interaction, Interactive Storytelling, Engagement, Agency

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1 INTRODUCTION

We are developing a social robot companion for children with cancer. The goal is to reduce medical traumatic stress by accompanying the child throughout their time in the hospital [27]. That is, on the one hand, why we are working on facilitating a supportive long-term interaction [26, 28] and, on the other hand, on designing concrete stress reducing interventions. In our research we set out to create a library of interaction design patterns, that together contribute to the stress reduction goal.

When developing a social robot that has to interact with people autonomously, its behaviors need to be explicitly specified and implemented, as opposed to working with a wizard-of-oz set-up [37]. These interactive robot behaviors are often designed to have a specific effect on people. Specifying the robot behaviors in a structured way, i.e. in the form of interaction design patterns, opens up the ability to efficiently validate, share, and reuse the robot behavior designs [29]. This allows us, as a community, to create a library of reusable and validated interaction design patterns (pattern library) that we can build upon.

In this paper we focus on expanding our pattern library with design patterns that can be used as a stress reducing intervention. Psychosocial interventions are an important part of pediatric oncology care [45]. There is a wide range of interventions focusing on different aspects of psychosocial care. For example, there are interventions focused at distracting children [23], supporting their information need [5], or using cognitive-behavioral therapy to improve their coping strategies [3].

A co-design session with a child-life specialist, responsible for managing the interventions, resulted in the concept of an interactive storytelling experience with the robot as a distractive intervention. Storytelling is an intervention that child-life specialists are familiar with [50]. The more the children are engaged by, and involved in, the storytelling experience, the more effective the intervention will likely be [11].

In this paper we specify three interaction design patterns that aim to increase engagement with the storytelling experience and to increase children's agency to become actively involved with the storytelling (sections 2 and 3). We validated these design patterns with a user study (N = 27, 8-10 y.o.) where school children engaged in an interactive (with design patterns) and plain (without design patterns) storytelling experience (sections 4 and 5). The collected video data proved to be particularly insightful about the nature of the child-robot relationship and children's responses to unexpected robot behavior. It allowed us to derive four lessons that help us improve the design patterns (sections 6 and 7).

2 RELATED WORK

There are only a few studies available that researched reducing stress and pain with social robots in a pediatric care setting. Results show limited, but promising, evidence for effective stress reduction, but no evidence for pain reduction [47]. From those studies we learn that, in order to be successful, the robot must be able to engage the children [4, 20] during a brief time (i.e. several minutes) surrounding the stressful event [23]. In this section we discuss related work regarding supporting engagement and agency with robotic storytelling.

2.1 Engagement

Both the robot and the story play a role in supporting engagement. It starts with the robot who initiates the engagement. It is inevitable that a child disengages and reengages throughout the storytelling experience [41]. It is the ratio of engaged/disengaged moments and the robot's ability to reengage the child that determines the effectiveness of the support.

Engagement requires attention, a cognitive resource, and is modulated by an affective component (e.g. enjoyment). A positive affect can increase the availability of cognitive resources that, for example, can be spend on reengagement [10]. When interaction is added to the storytelling experience, for example by letting the robot ask the child a question, explicit (re)engagement prompts are offered [16], which contributes to keeping the child engaged.

Engagement is especially supported when visual, auditory, and tactile stimuli are combined [12]. If we look at other successful robot storytellers, for example in the context of pediatric rehabilitation [35] or education [15, 25, 49], we learn that the robot's embodiment, as multimodal storytelling medium, is very suitable to provide multi-sensory stimuli. Children enjoy an expressive robot more [30] which can result in continued higher levels of engagement [25].

The story itself can also engage children by "transporting" them to the narrative world [17, 18]. Four factors are important for this to happen successfully. The child must be able to make sense of the story (narrative understanding) and have enough attention for the story (attentional focus). The more empathy or sympathy a child can feel for story characters (emotional engagement), the more likely they will be immersed in the story. Finally, the better the child is able to construct a mental image of the story (narrative presence), the easier they can be absorbed by it [7].

2.2 Agency

Engagement in storytelling is a well-studied concept in the field of interactive digital narratives [39] that, for example, includes gaming research [8]. Besides narrative transportation researchers identified agency as an important factor that influences the user's engagement [38].

Roth et al. (2016) argue that three aspects of agency are important for becoming engaged with an interactive story: the feeling of autonomy, competence, and affectance [38]. The more autonomous and competent users feel in their decision making [40] and the more impact they feel their decisions have immediately (local affectance) or overall (global affectance) on the narrative, the stronger they become engaged [24]. Via interaction with the robot, children can be given more agency over the story [9]. For example, children can be given choices about the story.

Another important part of agency is self-expression. The more children feel they can express themselves freely, the more involved they feel and the more their agency is facilitated [2]. The robot could, for example, invite the children to participate in a self-expression activity [9]. Additionally, active participation directs the attention towards the storytelling experience and thus increases engagement as well [38].

3 INTERACTION DESIGN PATTERNS

In this section we first discuss the content, structure, and creation process of the stories. Then, building upon existing pattern libraries [22, 26], we specify three new interaction design patterns that focus on supporting a child's engagement and agency.

3.1 Stories

The stories were created in a multi-faceted co-creative process involving a multi-disciplinary team. A group of professional writers held a few writing workshops for children in hospital and schools. The premise of this workshop was that children would write a story the robot could tell to other children in the hospital. The writers used these sessions as input to create a number of concepts for a series of stories. In groups the writers created a number of interactive stories following the concept. These stories were piloted once with school children[46] and improved again.

The selected concept keeps the stories close to the robot. The robot tells, from its own perspective, about adventures it had while doing different internships. The robot is trying to find out what kind of robot it wants to be. For example, it has done an internship as a telescope, fridge, and digger. Children are very eager to learn more about the robot. Using stories about the robot, told from its own perspective, gives the robot more of a personality. This potentially can contribute to more engagement and growing the child-robot relationship [6, 28, 42].

All the created stories use a three-act structure. In the first act (setup), the stories begins by establishing the context of the internship and the main characters (exposition). The robot is confronted with a problem (motorical moment). In the second act (confrontation), the robot tries to solve the problem to no avail (rising action). In the third act (resolution), all the tension converges (climax), a solution is presented, and the story winds down (falling action) and wraps up (denouement) [14, 48].

3.2 Robot Guided Narrative Decision-making

3.2.1 Problem. Giving children the ability to make decisions about the story is a concrete way to increase their agency and engagement [13, 24, 38, 40]. Two practical problems need to be addressed. The first is the question of how the child is going to make the decisions.

Each decision point creates a set of unique narrative branches, that branch out themselves when faced with a new decision, creating an exponential explosion of content that needs to be created. How to keep the branching problem contained?

3.2.2 Principle. We opted for letting the robot directly provide different decision opportunities, in the form of questions, during the story. This keeps the focus directed at the child-robot interaction, as opposed to using additional external attributes.

To address the branching problem we opted for three basic strategies. The first is to merge branches directly after a split, creating a shallow branching structure. The second is to delay the branching after a choice. The third strategy is to use a world state; a collection of narrative variables that are used throughout the story. The world state could, for example, include the color of the dress of the main character.

3.2.3 Solution. The robot tells a predefined story with a fixed set of decision points. At a decision point the robot asks the corresponding question. This pattern uses the same recognition and repair pipeline as specified by Ligthart et al. (2019) [26]. The child can verbally answer the question. If the robot's speech recognition fails, the robot will repeat the question, giving the child a second verbal answering attempt. If the second attempt fails, the robot will apologetically indicate it could not process the answer properly. It will list the answer options, allowing the child to answer by pressing the robot's feet (i.e. the Nao robot has buttons on its feet). If for what ever reason no answer was provided, the robot will continue with a default answer. There are three versions of this pattern.

3.2.4 Version 1: shallow branching. At a shallow branching decision point (see figure 1a) the robot asks a closed-ended question. A question containing between two and four explicit answer options [26], that each lead to a different story branch. For example, "What way do you think we should go? Through the swamp or through the woods?". In each branch the story continues explicitly referring to the decision. For example, "because we traveled through the woods ...". Directly after the first branched story node the branches merge again and continue onward.

3.2.5 Version 2: alternative ending. In the story node before the alternative endings (see figure 1b), the children are reminded that they made a choice earlier on and that they will now see the effects of their choice.

3.2.6 Version 3: world state choices. In the story node before the first occurrence of a world state variable (see figure 1c), a value needs to be assigned. The robot does this by asking a pseudo-open question. That are questions that do not list the answer possibilities explicitly and generally have a wider range of valid answers. However, there is still a finite set of prespecified answers required [26]. For example, "what is your favorite color?". If the child answers with "red", the story will continue with "what a coincidence, the dress of our hero is also red". A world state variable typically appears in multiple nodes throughout the story and aims to support both local and global affectance.

3.3 Co-reenactment

3.3.1 Problem. Listening to a story, even when you can answer a question once in a while, is still a relatively passive activity. Adding an active component that is relevant to the storytelling would further support engagement [39].

3.3.2 Principle. Using the robot embodiment and expressive capabilities (gesturing and sound) to add animations to the storytelling experience is a known recipe to make it more active [15]

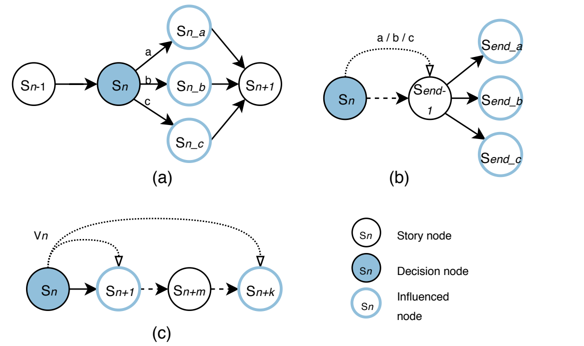

Figure 1: Narrative Decision-making strategies a) shallow branching, b) alternative ending and c) word state choices.

and engaging[51]. From previous studies we have observed that children have the tendency to mirror the robot's bodily expressions. Physical interaction adds an additional layer of engagement support [12]. The robot can encourage this by inviting the children to gesture together. This provides an opportunity for children to express themselves as well.

3.3.3 Solution. The robot uses animation and gestures to reenact certain scenes from its story. For example, pretending to be an elephant or race car driver. Before a selected animation the robot invites the child to join it. "Let's pretend to be an elephant together! In 3, 2, 1, start". Participation is optional. In any case, the robot will continue with it story after the animation.

3.4 Self-expressive Sound Effects

3.4.1 Problem. The storytelling experience primarily takes place in the auditory domain. Allowing children to express themselves more freely in this domain will support their agency and engagement [2, 9]. How to integrate children's vocal expression into the storytelling experience?

3.4.2 Principle. The robot has the ability to record and replay verbal expressions made by the child. To frame the expressions in a suitable way the robot can invite the child to record a sound effect. The children can comply the robot's request in anyway they see fit. The robot can use the recorded sound effects throughout the story. Additionally, adding sound effects to the story creates additional stimuli to increase engagement [1, 33].

3.4.3 Solution. The robot asks the child if they want to help the robot by making a particular sound. For example, "can you help me by making the sound of a squeaking mouse?". Followed by a count down before the robot start recording. For example, "squeak as a mouse in 3, 2, 1, start". At start the robot starts recording for 3 seconds. After the recording the robot would thank the child. The recording is played back, embedded in the story, at least once. For example, "when the truck backed up it squeaked as a mouse [play sound effect]".

4 METHOD

The first goal of the user study was to validate whether the design patterns support children's engagement and agency (i.e. assess the effectiveness). We tested this by comparing storytelling with and without the patterns. The second goal was to evaluate the user experience in terms of efficiency and satisfaction[1]. To not put this burden on children in the hospital, we evaluated this version with school children. The study evaluating whether an intervention with the design patterns is effective for stress reduction in the pediatric oncology setting is under preparation and its results will be shared in future work.

4.1 Participants

27 school children, 8 girls and 19 boys between 8 and 10 years old, participated in the experiment. The participants were recruited from the same class room by their teacher. The participants and their legal guardians signed an informed consent form before participating. This study (ECIS-2019-08) was approved by the Ethical Committee for Information Sciences of our institution.

4.2 Experimental Design

This study had a within-subject design. Participants were exposed to two different stories. One with all the design patterns (interactive) and one without (plain). Which of the stories contained the patterns, and whether the interactive story was first or second, were both counter balanced.

As dependent variables engagement, agency, and narrative transportation were measured during both stories. We furthermore measured the interaction design pattern efficiency and satisfaction and story satisfaction (see section 4.5).

4.3 Materials and Set-up

A V6 grey-white Nao robot (see figure 3) was used. Google's Dialogflow was used for speech recognition. The design patterns were implemented in an artificial cognitive agent[2] in the agent programming language GOAL [19]. A standard issue Dell laptop hosted a virtual server running the artificial cognitive agent controlling the robot. After starting a story, no manual interventions were necessary. A Sony HDR-handycam was used to record the interaction on video and audio. A raspberry Pi 3b+ with a light and a button (see figure 2) was used as a distractor instrument to measure engagement. The fridge and digger stories were used in the experiment.

The study took place in a small unused class room. A small rug was placed on the floor to indicate where the children could sit. The robot was placed in front of the rug (see figure 3). The distractor was placed to the left of the robot in such a way that it remained visible in the periphery of the participant's vision when they would look straight at the robot. The researcher remained in the room positioned behind the participant.

4.4 Procedure

Participants came to the experiment room one after the other. The robot told two stories. After each story the participant rated their

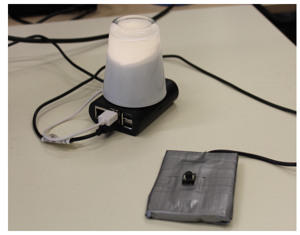

Figure 2: Distractor instrument to measure the attentional component of engagement

Figure 3: Set-up of user study. Children were seated on the rug.

experience. The plain story took about 3.5 min. to tell, the interaction added about 1.5 min. to the storytelling time. Approximate 20 minutes was used to instruct and interview the participant and collect the ratings.

At arrival, participants were reminded that they could leave without reason or consequences at any time. When ready, the participant was asked to take place on the rug in front of the robot. Participants were instructed about how to interact with the robot and that participating with a reenactment was optional. They were also instructed that if they would see the light come on they should press the button to turn it off. It was stressed that it would not influence the robot or the story in any way and that they didn't explicitly have to watch the light. Only when they would see it they should press the button. Inspections of the video recording confirmed that children adhered to these instructions and that the light distractor did not significantly interrupted the engagement with the robot.

4.5 Measures and Instruments

4.5.1 Engagement. We measured the cognitive component (attention) and the affective component (enjoyment) of engagement. We measured enjoyment by asking participants to indicate to what extend they would recommend the experience to their friends. With the light-based distractor instrument we measured attention. It is based on the Posner Cueing Task [34, 36] and the Peripheral Detection Task [31], both attention measuring methods from the cognitive psychology community.

As discussed in section 4.3, we placed a distractor near the robot (see figure 2). The stronger the participant focus their attention on the robot, the lower the chances are they perceive the light turning/being on and the longer it will take for the participant to press the button.

The light was turned on at three fixed moments during the story when the robot was not prompting for an explicit interaction. These moments were spread out over the three acts of the story. When the light was turned on an automatic timer starts running. The timer was stopped, and the light was turned off, when the participant pressed the button or after a fixed time. The latter was done to ensure the light stays off long enough before the next measuring moment. This way all participants had an equal opportunity to notice the light coming on the next instance.

[1]The ISO standard for Ergonomics in Human-System Interaction (ISO 9241-210) defines effectiveness, efficiency, and satisfaction as the three main user experience measures
[2]The code base and stories are available here: https://github.com/HeroProject/HeroGoalAgent/tree/experiment

Finally, we used a recall task as a proxy measurement of engagement [44]. The more the participants can recall about a story the better they paid attention [43] and the stronger they were engaged [32].

4.5.2 Agency. Different aspects of a child's agency were measured. Using the Player Experience of Need Satisfaction (PENS) instrument[21, 40], the feeling of autonomy, competence, and local and global affectance [38] were measured. Only the feeling of autonomy was measured for both stories.

The feeling of competence and affectance where only measured after the interactive story, because those items did not make sense to ask about a plain story. To be able to assess the performance of the design patterns to support the feeling of competence, local, and global affectance their ratings were compared with an artificial baseline. We assigned a moderately positive distribution of scores to the baseline (48% 4, 5; 33% 3; 19% 1, 2). The design patterns underperform on any one of the measures when their respective scores are not significantly higher than the baseline.

4.5.3 Design Pattern Efficiency. To assess the efficiency of the design patterns we logged the successes and failures of each interaction (e.g. a failed speech recognition attempt), the reasons an interaction failed (e.g. participant answered too late), how the participants responded to those failures (e.g. by speaking louder during the second attempt), and we asked the participant to rate the robots performance (perceived efficiency).

4.5.4 Design Pattern Satisfaction. In a semi-structured interview style we discussed the pros and cons of each interaction component with each participant.

4.5.5 Narrative Transportation. Narrative transportation was measured using a self-report questionnaire developed by Busselle and Bilandzic (2009)[7]. It contains four subscales with three items each: narrative understanding, attentional focus, narrative presence, emotional engagement. We translated the questions to Dutch, simplified the language to match the vocabulary of the participants, and adapted it to the context.

4.5.6 Narrative Satisfaction. We evaluated the content of the stories by asking the participants to rate how appealing each story was and by letting them make a reasoned choice between the two stories.

5 RESULTS

5.1 Engagement

5.1.1 Attention. A two-way repeated measures ANOVA was run to determine the effect of the design patterns on the distractor instrument response times for the three story acts. Data are mean ± standard deviation, unless otherwise stated. There was a statistically significant interaction between story and act, $F(2, 52) = 4.66$, $p = .014$, $partial\,\eta^2 = .15$. Therefore, simple main effects were run (see figure 4).

The response time was not statistically significantly different for the plain story ($23 \pm 25s$) compared to the interactive story ($19 \pm 20s$) during the first act, $F(1, 26) = .62$, $p = .44$. However, there was a statistically significant difference between a plain ($5.8 \pm 4.6s$) and an interactive ($16 \pm 20s$) story during the second act, $F(1, 26) = 8.8$, $p = .006$, $partial\,\eta^2 = .25$. And again a statistically significant difference between plain ($12 \pm 14s$) and interactive ($23 \pm 27s$) during the third and final act, $F(1, 26) = 4.6$, $p = .041$, $partial\,\eta^2 = .15$.

Furthermore, the response times for the plain story were statistically significantly different from each other, $F(2, 52) = 13.5$, $p < .001$, $partial\,\eta^2 = .34$. The response times for the interactive story did not statistically significantly differed from each other, $F(2, 52) = 1.5$, $p = .23$.

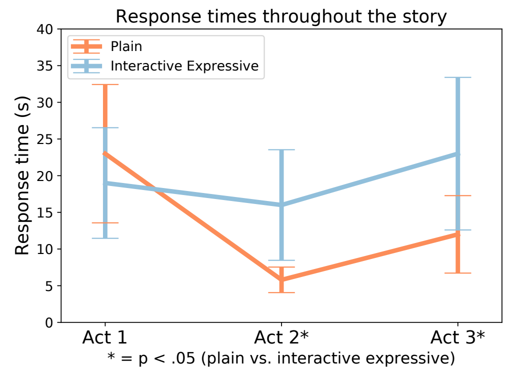

Figure 4: Response times (s) throughout the three acts of the story.

5.1.2 Enjoyment. Participants were asked to what extend they would recommend both experiences to their friends (enjoyment). 9 participants would recommend the interactive expressive experience more, while 2 would recommend the plain experience. The remaining 16 would recommend them equally. A Wilcoxon signed-rank determined that there was a statistically significant median difference in enjoyment scores between the interactive (4) and plain (3) storytelling experiences, $z = 2.1$, $p = .03$

5.1.3 Recall. Participants recalled statistically significantly more about the interactive story (2.8 ± 1.1) than the plain story (2.2 ± 1.0), $t(26) = 2.85$, $p = .008$, $d = .55$.

5.2 Agency

Of the 27 participants 19 (70%) felt more autonomous during the interactive story, while 3 participants felt less autonomous and 5 felt evenly autonomous in both conditions (see figure 5). A Wilcoxon signed-rank test determined that there was a statistically significant median difference in the feeling of autonomy between the plain (2) and interactive (3) stories, $z = 3.55$, $p < .001$.

The feeling of competence (of talking to the robot), local affectance, and global affectance where rated after the interactive story. An exact chi-square goodness-of-fit test was run to determine if the ratings outperform a threshold baseline (see figure 6). Because not every level in the 5-point rating scale was used, the scores were collapsed into a 3-point rating scale. The baseline had a distribution of 5 (19%) bad, 9 (33%) neutral, and 13 (48%) good scores. The feeling of competence ($\chi^2(2) = 6.12, p = .049$) and local affectance ($\chi^2(2) = 9.90, p = .007$) performed statistically significantly better

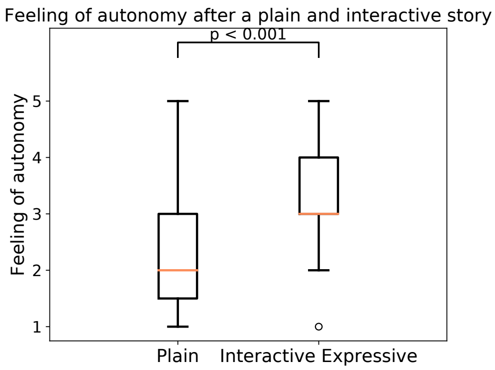

Figure 5: Feeling of autonomy scores after a plain and interactive expressive story.

than the baseline. Global affectance did not significantly performed differently from the baseline, ($\chi^2(2) = .31, p = .848$).

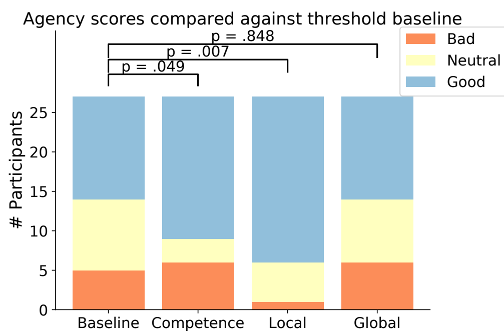

Figure 6: Plot showing the distribution of the agency scores after the interactive story compared to a threshold baseline.

5.3 Design Pattern Efficiency

Letting a robot operate autonomously and using automated speech recognition means that there will be failures. These failures were logged. In table 1 a breakdown is presented of the success rates and average number of failures for the two types of questions used in the interactive stories. Results show that participants on average needed multiple attempts to get their answer recognized by the robot. This was especially the result of the poor performance of the first attempt with an average success rate of 11%.

Table 1: Success rates of the answer recognition attempts

	Closed	Pseudo-open	Total Cumulative
1st attempt	4%	18%	11%
2nd attempt	67%	22%	54%
Touch repair	27%	50%	93%
No success	5%	10%	100%
Avr # failures	1.33	1.57	1.45

Analysis of the video data and logs showed that 40% of these failures were caused by an issue with the integration of Google's Dialogflow into our software. 20% of the failures was due to participants getting confused about what is expected of them. For example, because they misheard the robot, leading to an invalid answer. 17% of the failures was caused by the robot continuing while the participant was still thinking. Another 17% was caused by the participant answering too soft, too early, or too late, for the speech recognition to pick up on. The final 6% were unexpected (i.e. not prespecified) answers to a pseudo-open question.

The participants were very persistent after a failure occurred. In 92% of the cases the participant tried again by repeating an answer, often in a louder fashion (59%). After the remaining 8% of the failures a participant disengaged, because they were too demotivated or frustrated.

Finally, a Pearson's product-moment correlation was run to assess the relationship between the amount of failures and engagement, agency, design pattern efficiency, and narrative transportation. The results are summarized in table 2. This explorative step shows that failures negatively impacts how much participants can recall about a story and how well they perceive the efficiency of the design patterns. Furthermore, the amount of failures also make a story harder to understand and more difficult to be absorbed by. It, however, does not seem to (negatively) impact a participant's agency.

Table 2: Pearson's correlation (and p-values) of the amount of failure with the engagement, agency, design pattern efficiency, and narrative transportation. Statistically significant correlations are presented in bold.

Engagement			
Attention	Enjoyment	**Recall**	
-.05 (.80)	-.36 (.06)	**-.39 (.045)**	
Agency			
Feel. of Aut.	Feel. of Comp.	Local Aff.	Global Aff.
-.19 (.35)	-.17 (.40)	-.09 (67)	.09 (66)
Design Pattern Efficiency			
Perc. Eff.			
-.56 (.003)			
Narrative Transportation			
Nar. Underst.	Att. Focus	Emo. Eng.	Nar. Pres.
-.46 (.015)	.002 (.99)	-.33 (.09)	-.22 (.26)
Nar. Trans.			
-.43 (.027)			

5.4 Design Pattern Satisfaction

5.4.1 Robot Guided Narrative Decision-making. 16 (59%) participants agreed that making choices about the story by interacting with the robot adds to the experience. According to the participants, it made the story more fun (4) and it allowed them to use their own fantasy and creativity (4). All but one preferred the interactive story. They saw the potential of this pattern, but "the robot should listen better". 4 participants were indifferent and 7 thought it was not a success. Participants explained that the interaction was disruptive and made them wait too long (3), they prefer to just listen to the story (2), or the questions themselves were confusing or boring (2). All but two preferred the plain story. They liked the interactive story for story intrinsic reasons.

5.4.2 Co-reenactment. 21 (78%) participants agreed co-reenactment adds to the experience. Reasons to like it was that it was fun to move (6) or it made the story more funny or alive (10). A reason to not like it was that was unclear what was expected (3) or that they do not like to reenact (3). An important aspect was that it was optional (9). For most it was clear that it was optional, and that was explicitly listed as a good thing. "It's not for me, but I like to watch. It's good that I could decide for myself. I'm sure other children would like it". However, it was not clear enough for everybody. For example, "I want to have the [explicit] choice to participate, because now I had the feeling the robot did not listen to me". 14 participants co-reenacted both times, 3 only one time, and 10 participants just watched the robot reenact a scene from the story.

5.4.3 Self-expressive Sound Effects. 24 (89%) participants agreed that adding sound effects adds to the storytelling experience. Participants liked that it gave them the opportunity to add something to the story (6) and that they could hear themselves back in the story (9). 4 participants liked this pattern even though they experienced technical difficulties to record the sound effect. The 3 participants that did not agree that it adds to the experience all commented that they did not know what was expected of them.

5.5 Narrative Transportation

Using Wilcoxon signed-rank tests we determined that there were no statistically significant differences in the narrative transportation subscales as well as the overall score between a plain and interactive story, all $z's < |1.63|$ and $p's > .10$

5.6 Narrative Satisfaction

The two stories that were used in the user study were called 'fridge' and 'digger'. Participants rated how much the content of each story appealed to them. 9 participants found the fridge more appealing, 9 participants found the digger story more appealing, and 9 participants rated them equally. A Wilcoxon signed-rank test determined that there was no statistically median difference between both stories, $z = .00$, $p = 1.0$. Whether the story was interactive or not did not seem to influence the story satisfaction. 10 vs. 8. vs. 9 participants found respectively the interactive story, plain story, or neither more appealing, $z = .83$, $p = .41$.

Participants were also asked to make an explicit choice between both stories. The results again shown a split preference between stories. The fridge story was slightly more preferred (63%) and the interactive story was slightly more preferred (63%). The most frequently used arguments were story intrinsic (16 times). For example, the preferred story was funnier ("DJ strawberry was so funny") or more related to their interests ("My father works with diggers"). 8 participants mentioned the interactiveness as a reason to prefer a story. For example, "Because I could use my own fantasy, by saying stuff to the robot". 2 participants preferred the plain story, because the interactive story was too confusing for them.

6 DISCUSSION

6.1 Validation of Design Patterns

The interactive design patterns are designed to support children's engagement and agency. With our user study we aimed to validate that the patterns indeed have the desired impact. The results show that when the design patterns were employed during storytelling, children paid attention on a continued higher level to the robot, enjoyed the experience more, and could recall more about the story. In other words, the design pattern significantly support engagement.

Results also showed that the design patterns mostly support children's agency. Children feel significantly more autonomous when the design patterns are used. Children especially felt that their choices were directly used (local affectance) by the robot. They however did not experience that their choices had effect later on in the story (global affectance) to a satisfyingly degree. It should be made more clear what the effects of children's choices are throughout the story. Finally, most children felt competent to talk to the robot. There is, however, room for improvement to make it more accessible (one fifth of the children did not feel competent enough).

The parts of the design patterns that allowed children to express themselves were explicitly mentioned by children during the final interview and were generally highly appreciated. Children appreciate that via the questions the robot asks, they receive some creative control over the story. Children overwhelmingly (89%) appreciate that the robot records and uses their self-made sound effects.

The design patterns did neither significantly improve or inhibit the narrative transportation. A factor negatively influencing narrative transportation, and also recall, is the number of failures during the interaction. Failures can confuse or annoy children, making them (temporarily) lose track of the story. Children however are particularly persistent to get heard by the robot. They repeat their answer even louder. This is, presumably, why failures do not seem to negatively affect the attention towards the robot.

6.2 Lessons Learned

The video data showing how children responded to (un)expected robot behaviors and the design pattern efficiency and satisfaction metrics proved to be a valuable source for insights. In this section we present the four most important lessons we have learned. Lessons that help us understand the child-robot relationship better in general and to improve the design patterns in particular.

Improvements that reduce the number of interaction failures are especially necessary, because they interrupt the storytelling experience and inhibit children to be fully transported to the narrative world. 40% of the failures are caused by a software integration issue, which needs to be technically improved. However, 60% of the failures are caused by insufficient efficiency of the design patterns. The four lessons are aimed at improving the design pattern efficiency.

6.2.1 A lack of communicability is an engagement killer. We have observed that when, for example, the robot oddly pronounced a word, speaks too fast, or uses an unknown word, children get confused about what the robot expects of them. This causes 20% of the failures. Children seem to have an urge to accommodate the robot. Some feel ashamed they cannot accommodate the robot and disengage. Others try to answer anyway (robot: "should I open or close the door?", child: "Uhm? yes...") or ask the robot for clarification ("what is a pully?"). The robot does not recognize or acknowledge any of these responses. This often leads to temporary disappointment or frustration, and ultimately disengagement.

More piloting should identify parts of the interaction that are unclear. If the robot can adapts its talking speeds dynamically, for example based on the amount of (speech recognition) failures, it could accommodate children who interact better with a slower paced robot, while also keeping children who prefer a faster paced robot engaged.

6.2.2 Children need time to be heard by the robot. 17% of the failures are caused by children who where still thinking about an answer and therefore did not answer. Usually, they use the second speech recognition attempt to give that answer. However, this leaves them with only one speech attempt. It not only creates unnecessary pressure, especially on the slower thinking children, it also increases the risk of not getting heard by the robot. Video data shows that being heard by the robot is an important value for the children. Most speak up during the second attempt and some even talk during the final touch based attempt. If they are not being heard, children slowly get more restless, disappointed, or frustrated. Dynamically increasing the recognition time and adding an extra speech recognition attempt, when no answer is given the first time are two options to accommodate children who need more time to think.

6.2.3 Make (parts of the) interaction optional. Although the majority of the children saw value in, and appreciated, the design patterns, there also was a minority that expressed their concerns. Those children should not be overlooked. A part of the concerns, especially for the robot guided narrative decision-making pattern, were related to the inadequate efficiency of the pattern. However, children also expressed that they would have rather experienced the story without one or more of the patterns. Some children did not want to decide what happens in the story. Other children loved to see the robot dance, but did not care for dancing along. Allowing children to express their interaction preference will make the storytelling experience more inclusive.

6.2.4 Diversify the content. Results show that both stories were highly, but also robustly, appreciated. The story ratings were not affected by the presence of the design patterns. Neither of the stories was universally preferred over the other. Children each like different things for different reasons. Most children that preferred the plain story, made that choice because they liked that story better. Most children that explicitly indicated that they liked the interaction, preferred the interactive story, but not all. Some still would choose the plain story, simply because they liked the content better. This shows the power of the story. Having a diverse set of stories, possible decisions, animations, and options for custom sound effects would make the storytelling experience more appealing to a broader range of children.

6.3 Limitations

A limitation of our work is the sample size and diversity of the user study. Not only would more participants increase the statistical power. It would, especially if the sample was more diverse, give more insights into the interpersonal difference between children and what their needs and values are, in order for us to make our design more inclusive.

Another limitation is that we only validated the design for one encounter in a school setting with two specific stories. Although we believe the design principles are transferable to other stories and applicable in a more long-term clinical setting, this needs to be properly validated first. Luckily, the preparations for such a validation study are underway.

7 CONCLUSION

We have specified, and successfully validated, three new interaction design patterns that support children's engagement and agency during an interactive storytelling experience with a social robot. The first design pattern enables the robot to feasibly offer children choices about the story. The second design pattern enables the robot the invite children to together reenact parts of the story. The third design pattern enables the robot to record and replay sound effects made by the children.

A user study (N = 27, 8 - 10 y.o.) showed that children pay more attention to the robot, enjoy the storytelling experience more, recall more about the story, and feel more autonomous when the design patterns are used by the robot during storytelling. Children appreciate about the design pattern that it give them some creative control over the story, that their choices have an immediate effect, and that they can express themselves. The design patterns do introduce interruptions, caused by speech recognition failures, in the storytelling experience that inhibit narrative transportation and recall. 40% of the failures can be reduced by technical improvements to our software and 60% of the failures can be reduced by improving the efficiency of the design patterns.

We have identified four important lessons that we can use to improve the design patterns. Reducing points of confusion and giving the children more time to make themselves heard by the robot will improve the interaction efficiency and likely support engagement and agency even more. Allowing children to pick and choose from a diverse set of stories and interaction settings would make the storytelling experience more inclusive and appealing to a broader range of children.

Our work contributes to establishing an interaction design pattern library that will enable an autonomous robot to support pediatric oncology patients. The discussed validation study brings us one step closer to help reduce stress and show the children in the hospital what social robots are all about.

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